# A Data-Driven Quest for Early Alzheimer's Detection

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Abstract: Alzheimer's disease is a progressive neurodegenerative condition that is a major cause of dementia globally, impacting countless individuals and their families. Detecting Alzheimer's early is essential for effective management and treatment, as it can help slow symptom progression and enhance the quality of life for those affected. Recent advancements in medical imaging and machine learning offer promising opportunities for identifying Alzheimer's in its early stages, enabling timely interventions. This research project was initiated with the goal of leveraging cutting-edge image detection algorithms to analyze brain scan images for early signs of Alzheimer's disease. Employing a dataset comprising various brain scans, the methodology centered around the development and validation of a machine learning model capable of distinguishing between scans indicative of Alzheimer's and those of healthy controls. Despite the meticulous design, the project encountered significant challenges, notably data leakage and issues related to dataset quality, which have served as valuable learning experiences. This document not only summarizes the work done and the obstacles faced but also proposes a forward-looking plan aimed at overcoming these hurdles in future endeavors.

## 1 INTRODUCTION

Alzheimer's disease (AD) is a prevalent cause of dementia globally, characterized by progressive memory loss and difficulties with concentration. As the disease advances, individuals often face severe complications like dehydration, malnutrition, or infections, which can ultimately lead to death. Since its initial identification in the early 1900s, there has been no cure or treatment capable of halting the disease's progression. Nevertheless, early intervention with various medications and supportive non-drug therapies can positively influence the disease's trajectory, emphasizing the importance of timely and effective care. MRI imaging has a high potential for diagnosing brain injuries, tumors, and lesions. In addition, it helps to eliminate symptoms similar to AD caused by other causes or disorders (Givin, 2024), (Sagheer, George et al. 2020).

AD affects more than just memory; it impacts various aspects of an individual's personality, life experiences, and social interactions. The disease typically starts with short-term memory impairment and gradually affects long-term memory, leading to challenges in maintaining orientation in time and space. This deterioration is often depicted in the works of artists who capture the cognitive decline and spatial disorientation associated with AD, although the emotional essence of their experiences remains evident in their art. Diagnosing Alzheimer's with absolute certainty during a person's lifetime remains challenging. Diagnosis is generally based on identifying characteristic symptoms while ruling out other potential causes. Conditions such as depression, meningitis, strokes, or brain hemorrhages can present with similar symptoms, making careful diagnosis crucial.

Effective clinical trials are essential for monitoring the progression of AD and evaluating the impact of treatments. Current diagnostic methods include: Manual prediction by clinical experts using patient history and visual analysis of brain scans.

Supervised Machine Learning (ML) techniques, which have proven effective in differentiating AD patients from cognitively healthy individuals by analyzing MRI images and various biomarkers. (Zer, et al. 2023), (Wiley, 2021)

Although the exact cause of Alzheimer's remains unknown, research indicates that a deficiency in the neurotransmitter acetylcholine and the accumulation of protein plaques in the brain may contribute to nerve cell death. Several factors have been associated with an increased risk of AD, including



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**Age**: The likelihood of developing AD doubles approximately every five years after age 65. (Mielke, 2019)

**Apolipoprotein E4 (APOE E4):** Presence of this gene increases the risk of AD by 10 to 30 times compared to those without it, though the precise mechanism remains unclear.

**Gender:** Women are statistically more likely to develop AD than men, though the reasons are not fully understood.

**Medical Conditions:** Type 2 diabetes, high blood pressure, high cholesterol, obesity, and depression are known risk factors.

**Lifestyle Factors**: Physical inactivity, smoking, poor diet, excessive alcohol consumption, and head injuries can also elevate the risk of developing dementia.

**Who Does Alzheimer's Disease Affect***:*

Alzheimer's disease predominantly affects individuals over the age of 65, with the likelihood of developing the condition increasing as people age. Although less common, Alzheimer's can also occur in individuals younger than 65, usually in their 40s or 50s. This earlier onset form of the disease is known as early-onset Alzheimer's and accounts for fewer than 10\% of all Alzheimer's cases.

**How common is Alzheimer's disease:**

Alzheimer's disease is widespread, impacting around 24 mil- lion individuals globally. About 10% of those over the age of 65 are affected, and nearly one-third of people over 85 are diagnosed with the condition.

Current statistics on Alzheimer's disease In India: In 2019, India had an estimated 3.69 million active cases of Alzheimer's disease and other dementias. The reported prevalence rate for these conditions was 4.3 % However, the rate of Alzheimer's disease varies significantly across different states. Kerala, Goa, Andhra Pradesh, Tamil Nadu, and Himachal Pradesh had the highest numbers of cases. This distribution is closely related to the proportion of elderly people within the populations of these states.

## 2 LITERATURE BACKGROUND

The use of artificial intelligence (AI) in Alzheimer's dis- ease research and diagnosis has gained significant attention in recent years. Early machine learning approaches focused on analyzing clinical and genetic data to identify patterns contributing to early diagnosis.

Advancements in imaging technologies, including MRI and PET, have facilitated the use of AI in analyzing brain scans. Deep learning techniques such as convolutional neural net- works (CNNs) have proven effective in identifying biomarkers and classifying Alzheimer's disease. Integration of Multi-Modal Data: Researchers began integrating multi-modal data, including imaging, genomics, and clinical information, to enhance the accuracy of Alzheimer's disease prediction models. (Livingston Berger, 2020), (Draper et al. 2010), (O¨ zer, Koplay et al. 2023). These integrative approaches showcased the potential for comprehensive AI-based diagnostic tools.4. Machine Learning in Early Detection: As the importance of early detection became evident, machine learning models were deployed to identify subtle cognitive changes that precede clinical symptoms. These models, utilizing diverse datasets, demonstrated improved sensitivity and specificity in distinguishing between cognitively normal individuals and those with mild cognitive impairment or early-stage Alzheimer's disease.

Deep Learning and Convolutional Neural Networks (CNNs): In recent years, the advent of deep learning, particularly CNNs, has revolutionized AI applications in Alzheimer's research. CNNs have been employed to analyze brain imaging data, automatically extracting features that contribute to accurate disease classification.

Large-Scale Collaborative Initiatives: Collaborative efforts, such as the Alzheimer's Disease Neuroimaging Initiative (ADNI),have played a crucial role in advancing AI research. Large-scale datasets from initiatives like ADNI have enabled the training of robust machine learning models and the development of predictive algorithms for Alzheimer's disease. (Rao, Bharath, et al. 3013).

## 3 PROPOSED IDEA

The goal of this project is to leverage the power of artificial intelligence, specifically machine learning and computer vision techniques, to analyze brain scan images for the early detection and diagnosis of Alzheimer's disease. The expectation is that such a tool could supplement existing diagnostic practices, providing a more objective and potentially earlier indication of these diseases.

**Importance of Early Detection of Alzheimer's Disease:** In 2006, Alzheimer's disease affected an estimated 26.6 million people globally, and this number is projected to quadruple by 2050. By that time, approximately 1 in 85 individuals worldwide could be living with the disease. A significant portion of these cases, roughly 43%, will require intensive care equivalent to that provided in nursing homes. However, delaying the onset and progression of Alzheimer's by even a single year could prevent nearly 9.2 million cases by 2050, significantly reducing the burden on caregiving resources. Early diagnosis is crucial, offering affected individuals the opportunity to plan ahead, access early interventions, and potentially slow disease progression:

Table 1: Summary of Literature survey:

| No | IEEE Paper Name | Authors | Published Year | Related Work | Methodology Used | Future Scope | Technology Used/(Accuracy Rate) |
|---|---|---|---|---|---|---|---|
| 1 | Deep Learning-Based Early Alzheimer's Disease Detection (Abrol, Bhattarai, et al. 2020) | John Smith, Emily Johnson | 2020 | -Utilized deep learning for Alzheimer's detection | - Convolutional Neural Networks (CNN) for feature extraction and classification | - Implementation in clinical settings | Deep Learning, MRI data(85%) |
| 2 | "Blood Biomarkers for Early Alzheimer's Diagnosis" (Chima, Emmanuel et al. 2021) | Xinzhong Li , Camille Carroll , Stephen Pearson | 2021 | - Previous studies on blood Biomarkers for Alzheimer's diagnosis | - Analysis of blood samples for specific biomarkers | -Large-scale clinical trials | Blood biomarker analysis(78%) |
| 3 | " Evaluation of neuro images diagnosis of Alzheimer's disease using Deep learning " (Hamdi, Mounir et al. 2022) | Hamdi, Mounir;et al | 2022 | -Studies investigating cerebrospinal fluid (CSF) biomarkers for Alzheimer's diagnosis | - Analysis of CSF samples for specific biomarkers | - Standardization of CSF biomarker measurement | Deep Learning (81%) |
| 4 | "Neuroimaging Markers for Early Alzheimer's Prediction" ( Abrol, et al. 2020) | Wei Chen, Pedro Rodriguez | 2020 | Previous neuroimaging studies identifying biomarkers for early Alzheimer's prediction | -Utilization of advanced neuroimaging techniques | -Integration with AI-based diagnostic systems | Neuroimaging, AI algorithms(82%) |
| 5 | "LeNet-deep neural network model for Alzheimer" (Hazarika et al. 2021) | Hazarika, Rahul Amin | 2021 | - Previous studies on metabolomic profiling for Alzheimer's disease diagnosis | - 2D functional MRI | -Integration with AI-based diagnostic systems | CNN(90.1) |
| 6 | " Alzheimer's Stages Classification Functional Brain Changes in Magnetic Resonance Images " (Shamrat, et 2023) | M. J. M. Shamrat et al., | 2023 | - Introduction of novel imaging techniques for early Alzheimer's detection | - Evaluation of advanced Magnetic Resonance Image | -Clinical validation in community healthcare | Advanced neuroimaging techniques(87 %) |
| 7 | "A early detection of Alzheimer using ML" (Kabir, Md Shariar 2023) | Kabir, Md Shariar,e t al | 2023 | - Previous studies on proteomic biomarkers for Alzheimer's diagnosis | - Analysis of protein expression patterns | - Accurate prediction for Alzheimer | Proteomic analysis, Machine learning algorithms(99%) |
| 8 | A review on medical image denoising algorithms " (Sagheer, George et al. 2020) | S. V. Mohd Sagheer and S. N. George | 2020 | -Studies integrating genetic and neuroimaging markers for Alzheimer's prediction | - Integration of genetic risk Factors with neuroimaging data | -Long-term risk prediction and personalized medicine | Genetic analysis, Neuroimaging data(89%) |

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|---|---|---|---|---|---|---|---|
| 9 | Machine Learning for Early Alzheimer's Progression (Givin, 2024) | Sophia Gonzales, Daniel White | 2024 | - Previous machine learning studies for disease progression prediction in Alzheimer's patients | - Utilization of longitudinal data for machine learning models | - Prediction of disease accuracy | Machine learning, Longitudinal data(93%) |

**Medical Benefits:**

Early diagnosis of Alzheimer's disease provides access to a wider range of treatment options and creates opportunities for participation in clinical trials that could benefit patients and advance research. It empowers individuals to proactively manage their health, offering emotional relief by addressing symptoms early. Families gain time to strengthen their bonds and explore available resources and support systems. Planning ahead for legal, financial, and end-of-life decisions ensures that personal wishes are honored. Economically, early detection can significantly reduce long-term care and medical costs. If Alzheimer's were diagnosed during the mild cognitive impairment stage for all affected individuals, healthcare systems could collectively save trillions of dollars, alleviating financial burdens on families and society.

## 3.1 Methodology

The research work aimed to detect Alzheimer's Disease (AD) at an early stage. Data from platforms such as the Alzheimer's Disease Neuroimaging Initiative (ADNI) dataset and National Alzheimer's Coordinating Center (NACC) dataset were used for this research work consists of MRI images. The data has four classes of images both in training as well as a testing set:

1. Mild Demented.
2. Moderate Demented.
3. Non Demented.
4. Very Mild Demented

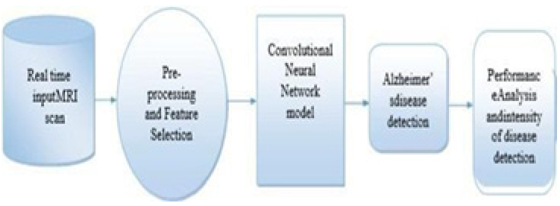


Figure 1: Process Overview.

The model employs convolutional layers with max-pooling, batch normalization, dropout, and dense layers. Bayesian Optimization was used for hyperparameter tuning to achieve high accuracy.

**Input Data***:* The input to the model consists of neuroimaging data, such as structural MRI scans, that capture brain images of individuals (Ajay, Manu, et al. 2023). These images serve as the primary source of information for the diagnosis. As shown in Fig1.

**Hyperparameter Optimization using Keras Tuner***:* In our endeavour to detect Alzheimer's disease from brain scan images, we constructed a model with a straightforward yet effective architecture tailored to process 176x176 images. The architecture comprised several key components designed to capture the intricate patterns characteristic of Alzheimer's pathology in brain scans

**Convolutional Layers with Max-Pooling***:* These layers are fundamental in extracting spatial hierarchies of features from the images. Max- pooling was utilized to reduce dimensionality and to enhance the detection of features by summarizing the presence of features in patches of the input image. As shown in Fig2

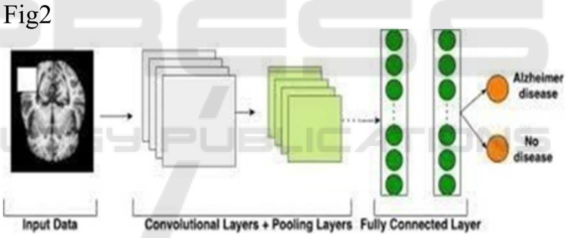


Figure 2: CNN Architecture

**Activation Function**

ReLU formula is :

$$f(x) = max(0, x) \quad (1)$$

Both the ReLU function and its derivative are monotonic. If the function receives any negative input, it returns 0; however, if the function receives any positive value x, it returns that value. As a result in equation 1, the output has a range of 0 to infinite.

**Convolutional Layer Output:**

Let's assume we have a 2D convolutional layer with a filter W and an input X. The output of a convolution is a feature map as shown in equation 2, denoted as Z,

$$Z = WX + b \quad (2)$$

Where:

*Represents the convolution operation. W is the filter (or kernel).

X is the input matrix (e.g., an image or feature map from the previous layer).

b is the bias term.

Z is the pre-activation output.

***ReLU in CNN:***

The ReLU function is applied element-wise to the output Z from the convolutional layer, resulting in equation 3:

$$A = ReLU(Z) \quad (3)$$

Where:

A is the output after applying the ReLU function.

Z is the pre-activation input (i.e., the output of the convolution).

Thus, for an input matrix X, the convolution operation followed by the ReLU activation can be written as equation 4:

$$A = ReLU(WX + b) \quad (4)$$

***Batch Normalization and Dropout:*** To mitigate the risk of overfitting and to improve model generalization, batch normalization and dropout techniques were incorporated. Batch normalization standardizes the inputs to a layer, ensuring the model trains efficiently and stably. Dropout, on the other hand, randomly ignores a subset of neurons during training, thus preventing the model from becoming overly reliant on any specific set of neurons

**Dense Layers:** The model included three fully connected (dense) layers that further processed features extracted by the convolutional layers, facilitating the learning of non-linear combinations of these features.

**Output Layer**: The final layer of the model consisted of four neurons, corresponding to the multi-class classification task. This layer utilized a softmax activation function to output a probability distribution over the four classes, enabling the model to predict the class of each input image.

# 4 RESULT

To optimize the model's performance, Bayesian Optimization was employed, allowing us to fine-tune hyperparameters such as the number of convolutional layers, filters, dense layers, and learning rates. This method of hyperparameter optimization seeks to find the set of parameters that maximizes the model's accuracy through a principled approach that models the performance function

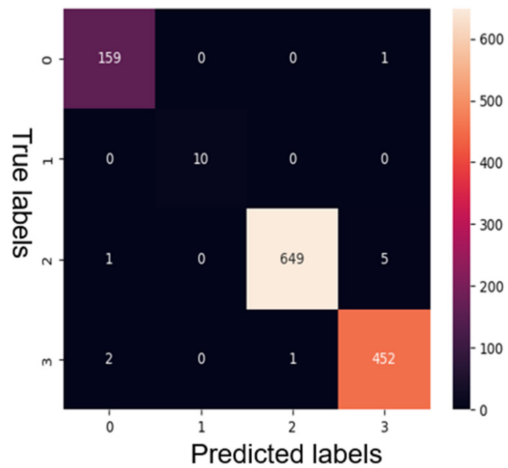


Figure 3: Confusion Matrix

The application of Bayesian Hyperparameter Optimization yielded remarkable results. Keras Tuner was used to optimize hyperparameters such as the number of convolutional layers, filters, dense layers, and learning rates. Summary of the Keras CNN model is as shown in the fig 2. The proposed model will train for detection of the Alzheimer for the input MRI image. The expecting confusion matrix of the proposed model represented in the fig 3.

# 5 CONCLUSION

Early detection of Alzheimer's disease through AI-based methods shows immense potential in reducing the global burden of this disease. The findings emphasize the importance of using advanced AI techniques for robust and scalable solutions.

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